



# **BIOMECHANICS FOR IMPROVED FIELD BOOTS**

Carolyn K. BenseL, Ph.D.  
U.S. Army Natick Soldier Center  
Natick, MA 01760-5020

DSN: 256-4780; Comm: (508) 233-4780  
E-Mail: [Carolyn.BenseL@Natick.Army.Mil](mailto:Carolyn.BenseL@Natick.Army.Mil)



# ***Boot Program Objectives***

- Reduce occurrence of stress-related foot and leg injuries by 10-15%
- Enhance comfort and locomotor efficiency of the wearer



# ***Boot Program Overview***

- **Designed/fabricated three generations of prototype boots based on desired performance characteristics**
- **Submitted prototypes to lab-based physical and human testing, and small-scale field testing**
- **Down-selected/Modified/Redesigned prototypes based on test findings.**
- **Tested final prototypes in large-scale prospective study of lower extremity injuries among military trainees**



# ***Desired Boot Characteristics***

***Desired characteristics identified through physical and human testing of standard military and commercial footwear***

- **Impact properties: Peak acceleration < Std. combat boot by 50%. Time to peak acceleration > Std combat boot by 50%**
- **Forefoot flexibility: < Std. combat boot by 20%**
- **Rearfoot stability: No more than 30% < Std. combat boot**
- **Outsole abrasion resistance: Equal to/better than Std. combat boot**



# ***Desired Boot Characteristics***

***Desired characteristics identified through physical and human testing of standard military and commercial footwear***

- **Outsole bond strength: Equal to/better than Std. combat boot**
- **Resistance to water penetration: Equal to/better than Std. combat boot**
- **Water retention: Equal to/better than Std. combat boot**
- **POL resistance: Equal to/better than Std. combat boot**



# ***Prototype Boots***

## ***Features in All Three Prototype Concepts***

- **Last**

- Same as standard boot (i.e., MIL-5)

- **Insert**

- Full length
- Molded, contoured polyurethane with cambrelle cover

- **Upper**

- Soft temper leather
- Wide, foam-padded collar covered with glove leather
- Interior lining in vamp
- Boot top height lower than standard boot



# **Prototype Boots**

## **Sole Construction**

**Mod ICB: Same sole construction as USMC infantry combat boot (i.e., polyurethane midsole and rubber outsole cemented to base sole)**

**Cement: Polyurethane midsole cemented to rubber outsole**

**Inject Molded: Direct injected, polyether polyurethane midsole with pre-molded rubber outsole**



# ***Prototype Boot Testing***

- **Purpose**

To determine whether or not prototype boots reduce incidence of lower extremity injuries compared with Std.

- **Participants**

1506 men and women undergoing 9 weeks of basic infantry training at Fort Jackson, SC

- **Protocol**

- Issued 3 test boots and std. boots randomly at start of training
- Recorded all sick calls made for lower extremity complaints
- Inspected lower extremities and boots on 3 occasions during training cycle





# ***Prototype Boot Testing***

***Study Sample Sizes (Men = 799;  
Women = 707)***

<u><b>Boot Type</b></u>	<u><b><i>n</i></b></u>	<u><b><i>%</i></b></u>
Mod ICB	177	11.8
Cement	188	12.5
Injection molded	201	13.3
Std. leather	940	62.4
<b>TOTAL</b>	<b>1506</b>	<b>100</b>



# ***Prototype Boot Testing***

## ***% Trainees Who Failed to Complete Training***

<b><u>Boot Type</u></b>	<b><u>Any Reason</u></b>	<b><u>Overuse Injury</u></b>
Mod ICB	15.8	4.0
Cement	14.4	1.6
Injection molded	14.9	3.0
Std. leather	13.3	3.5

**NO SIGNIFICANT BOOT DIFFERENCES ( $p > .05$ )**



# Prototype Boot Testing

*% Trainees Attending Sick Call or Having Training Restriction*

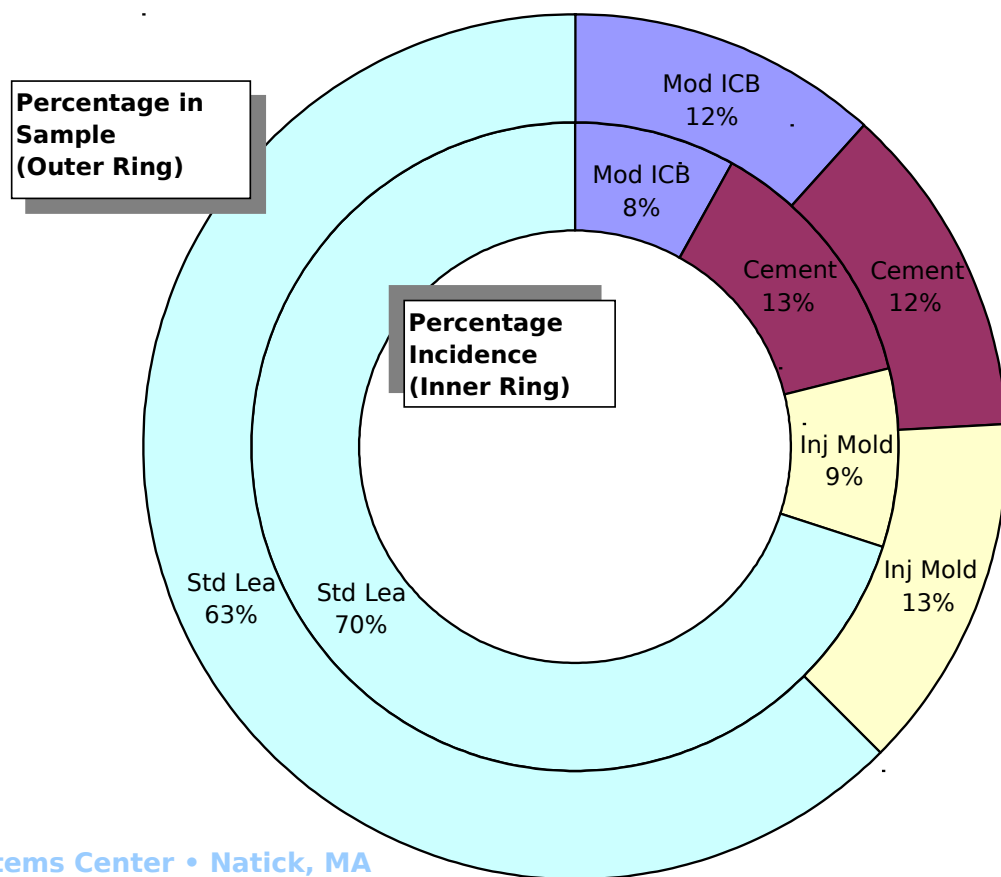
<u>Boot Type</u>	<u>At Least 1 Sick Call</u>	<u>At Least 1 Restricted Day</u>
Mod ICB	40.1	24.9
Cement	45.2	26.1
Injection molded	44.3	26.9
Std. leather	50.8	30.7

**Mod ICB SIGNIFICANTLY FEWER SICK CALLS THAN Std. Leather ( $p < .05$ ). NO DIFFERENCES IN RESTRICTED DUTY DAYS**



# Prototype Boot Testing

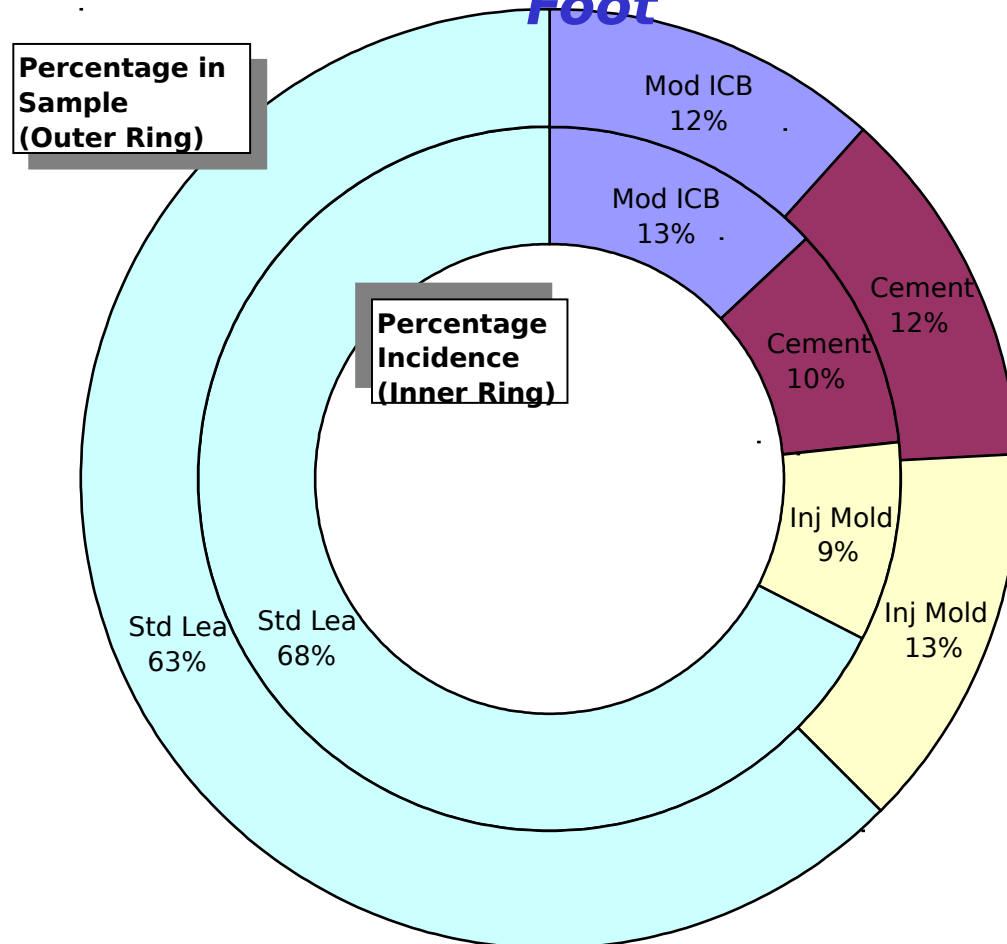
## Overuse Disorders of the Lower Leg





# Prototype Boot Testing

## Overuse Disorders of the Foot





# Prototype Boot Testing

*% Trainees With At Least One Overuse Injury*

<u>Injury Site</u>	<u>Mod ICB</u>	<u>Cement</u>	<u>Inj. Molded</u>	<u>Std. Lea.</u>
Knee	15.8	19.7	13.4	16.7
Lower leg	9.0	13.8	9.4	15.3
Ankle	4.0	6.4	7.0	7.2
Foot	14.7	11.7	9.0	14.6
Knee to Foot	28.8	36.2	28.9	39.6

**Mod ICB and Inj. Molded FEWER LOWER LEG INJURIES THAN Std. Leather BY 6-8% ( $p < .05$ ).**

**Mod ICB and Inj. Molded FEWER LOWER EXTREMITY INJURIES THAN Std. Leather BY 11% ( $p < .05$ ).**



# Prototype Boot Testing

## *Injury Incidence (RR): Prototypes Compared With Std. Leather*

<u>Injury Site</u>	<u>Mod ICB</u>	<u>Cement</u>	<u>Inj. Molded</u>	<u>Std. Lea.</u>
Knee	0.95	1.18	0.80	1.00
Lower leg	0.59	0.90	0.62	1.00
Ankle	0.55	0.88	0.96	1.00
Foot	1.01	0.80	0.61	1.00
Knee to Foot	0.73	0.91	0.73	1.00

**RISK OF LOWER LEG INJURY LESS WITH Mod ICB OR Inj. Molded THAN WITH Std. Leather BY 40% ( $p < .05$ ).**

**RISK OF FOOT INJURY LESS WITH Inj. Molded THAN WITH Std. Leather BY 40% ( $p < .05$ ).**